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Three new exotic species of ants (Hymenoptera, Formicidae) for Madeira, with comments on its myrmecofauna

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Abstract

Three new exotic species of ants are recorded for the Macaronesian island of Madeira: *Cardiocondyla obscurior* Wheeler, 1929, *Lepisiota capensis* (Mayr, 1862) and *Pheidole navigans* Forel, 1901. The well-known invasive *Pheidole megacephala* is now rare on Madeira, possibly because of competition with *P. navigans*. We did not come across the Argentine ant – *Linepithema humile*, which was once very common in the Funchal area. Despite extensive searching, the presumed endemic *Temnothorax wollastoni* (Donisthorpe, 1940) remains unknown other than from the type material. Presence, abundance and extinction of invasive and exotic ants are dynamic processes and we stress the importance of continuous sampling.

Keywords

Cardiocondyla obscurior, exotic, invasive, *Lepisiota capensis*, Madeira, myrmecofauna, *Pheidole navigans*

Introduction

Oceanic islands tend to have depauperate ant faunas and they are often notable for their assemblages of exotic and invasive species, which impact island faunas disproportionately (Williams 1994; Wetterer 1997; Rizali et al. 2010). The island of Madeira's ant fauna has been well studied and it stands out for its history of observations on invasive species (Wetterer et al. 2006, 2007).

Madeira occupies some 737 km^2 and is situated in the North Atlantic Ocean (approx. 32°44'N, 17°00'W at its centre), west of Morocco and north of the Canary Islands. An Autonomous Region of Portugal, it forms part of the volcanic Macaronesian group of archipelagos, along with the Azores, Selvagens, Canary Islands and Cape Verde. The climate in Madeira is subtropical with a range of bioclimates, the northwestern part of the island being the wettest and the southeast the driest. The steep, northern half of the island hosts native laurel 'laurisilva' forests, which are humid, lush and green throughout the year.

Following the Portuguese settlement in the early 1400s, Madeira quickly became an important centre for commerce, particularly between Europe and the New World, with new plants and animals from across the globe imported to Madeira prior to distribution to mainland Portugal and the rest of Europe (Wetterer et al. 2007). The history of myrmecology in Madeira is summarised in Wetterer (2006) and Wetterer et al. (2006). Two highly destructive ant species, the big-headed ant *Pheidole megacephala* (Fabricius, 1793) and Argentine ant *Linepithema humile* (Mayr, 1868) – both identified among 100 of the world's worst invasive alien species by the IUCN Invasive Species Group (Lowes et al. 2000) – were first recorded as exotics from Madeira, and they underwent apparent population explosions here in the 1850s and 1890s respectively (Heer 1852; Schmitz 1896; Wetterer et al. 2006, 2007). Madeira has since been synonymous with invasive ants, although Wetterer et al. (2006) subsequently found their distributions to be limited on the island, with little penetration of native habitats.

28 species of ant have so far been recorded from Madeira, of which ten are presumed native and one endemic (Wetterer et al. 2006, 2007). The last work on the Madeiran myrmecofauna was published by Wetterer et al. (2007), who recorded 23 species of ants including ten new to the island. Most of the material for that publication was collected in 2002. Therefore, it has been some 20 years since a survey was last conducted in Madeira and new invasive species may be expected. It is also a useful point at which to compare the current myrmecofauna to past observations. Here, we report three new exotic species for the island's fauna. We also compare our observations of well-known invasive ants to those of previous authors. Finally, we comment on *Temnothorax wollastoni* (Donisthorpe, 1940), which remains unlocated since it was described.

Methods

Trips to Madeira were conducted by the authors in 2014 and 2021. During 2014, ants were collected sparingly from seven sites by KB. These included minors of a small *Pheidole* sp. which were collected from two locations in Funchal. Without majors, the species was impossible to identify but it appeared to belong to the *flavens*-group.

In 2021, ants were collected intensively at 22 sites by RG, from various locations around Madeira (Table 1 for all locations, 2014–2021). Methods focussed on direct manual searching, leaf litter reduction using a Winkler bag sieve, and baiting using tinned tuna (protein). Sampling was not systematic: sites were selected by combining visits to sites already sampled by previous researchers with opportunistic sampling of favourable sites holding a representative range of native habitats.

One of the primary goals of this trip was to collect majors of the unidentified *Pheidole*. Bait was used to attract majors of the unknown species of the *flavens*-group. We also searched for the presumed Madeiran endemic *Temnothorax wollastoni* (Donisthorpe, 1940), which hasn't been recorded again since its discovery by Wollaston (BM 1858-21), but which is thought unlikely to have disappeared (Wetterer et al. 2006, 2007). The most similar species to *T. wollastoni* is *Temnothorax gaetulus* from northwest Africa (Santschi 1923) (Wetterer et al. 2007), which belongs to the *exilis*-group of species (Cagniant and Espadaler 1997). *Temnothorax gaetulus* is found in mountain steppe habitat with spiny, xerophytic vegetation (Cagniant and Espadaler 1997). We thus thought that *T. wollastoni* would likely be a ground-dwelling inhabitant of steppe or xeric habitat, but we used all methods that we typically employ to search for *Temnothorax*: searching on the ground, under stones, between cracks in rocks, under moss, on vegetation, in leaf litter, within hollow twigs on the ground or on shrubs and trees.

Ants were identified using all available resources (e.g., Antweb images http://www.antweb.org, Wilson (2003) and Sarnat et al. (2015) for the *Pheidole*, and comparison of ants in the personal collection of the first author for *Cardiocondyla* and *Lepisiota*). All material is leg. and det. R. Guillem, unless otherwise stated. All material collected is housed in the private collection of R. Guillem, which is held at the Gibraltar Botanic Gardens.

Table 1. Localities at which ants were collected during 2014 (KB) and 2021 (RG).

No.	Locality	Date	Coordinates	Elevation	leg
1	Pico do Arieiro	2.9.2014	32°44.18'N, 16°55.81'W	1760m	KB
		24.6.2021	32°44.13'N, 16°55.68'W	1800m	RG
2	Levada das Rabaças	4.9.2014	32°45.24'N, 17°01.53'W	1040m	KB
3	Paúl da Serra Plateau	4.9.2014	32°45.46'N, 17°05.83'W	1425m	KB
4	Bica da Cana	27.6.2021	32°45.29'N, 17°03.52'W	1560m	RG
5	Pestana Carlton Hotel, Funchal	5.9.2014	32°38.49'N, 16°55.35'W	20m	KB
6	Madeira Botanic Gardens	6.9.2014	32°39.75'N, 16°53.78'W	290m	KB
		23.6.2021	32°39.69'N, 16°53.73'W	280m	RG
7	Monte Palace Tropical Gardens	23.6.2021	32°40.42'N, 16°54.10'W	520m	RG
8	Parque Santa Catarina, Funchal	7.9.2014	32°38.75'N, 16°54.89'W	40m	KG
		22.6.2021	32°38.75'N, 16°54.85'W	38m	RG
9	Funchal Promenade	7.9.2014	32°38.80'N, 16°54.55'W	12m	KB
		26.6.2021	32°38.80'N, 16°54.54'W	12m	RG
10	Funchal Promenade	26.6.2021	32°38.78'N, 16°54.52'W	7m	RG
11	Jardim do Almirante Reis, Funchal	7.9.2014	32°38.85'N, 16°54.10'W	14m	KB
		23.6.2021	32°38.84'N, 16°54.08'W	14m	RG
12	Jardim Municipal do Funchal	23.6.2021	32°38.86'N, 16°54.69'W	33m	RG
13	Machico Municipal Garden	22.6.2021	32°43.05'N, 16°45.88'W	27m	RG
14	Machico Cemetery	22.6.2021	32°42.94'N, 16°45.97'W	25m	RG
15	Caminho das Voltinhas, Machico	22.6.2021	32°42.81'N, 16°45.88'W	75m	RG
16	Portelinha, Machico	22.6.2021	32°42.90'N, 16°46.24'W	230m	RG
17	Praceta 25 de Abril, Machico	22.6.2021	32°43.01'N, 16°45.94'W	14m	RG
18	Church Nossa Senhora da Conçeicão, Machico	22.6.2021	32°43.13'N, 16°45.99'W	14m	RG
19	Machico beach front	22.6.2021	32°43.13'N, 16°45.77'W	10m	RG
20	Ribeiro Frio	24.6.2021	32°44.01'N, 16°53.26'W	920m	RG
21	Towards Fajã da Nogueira	25.6.2021	32°44.58'N, 16°53.65'W	520m	RG
22	Praia da Ribeira do Faial	25.6.2021	32°47.54'N, 16°50.94'W	12m	RG
23	Parque Ecologico do Funchal	25.6.2021	32°42.14'N, 16°54.18'W	1130m	RG
24	Ponta de Sao Lourenço	6.9.2014	32°44.63'N, 16°42.05'W	70m	KB

Results

Sites and species recorded are provided in Tables 1, 2. An up-to-date checklist of all species recorded from Madeira so far is also provided in Table 3. New species to the island are discussed below.

Cardiocondyla obscurior Wheeler, 1929 (Fig. 1)

4 sites: 6. Madeira Botanic Gardens (23 Jun 2021), 2 workers on a wall; 10. Funchal Promenade (26 Jun 2021), 11 workers on ground; 11. Jardim do Almirante Reis (7 Sep 2014), 24 workers in lawn and planters; 18. Machico centre (22 Jun 2021), 5 workers in planters outside church.

The species was originally described from Thailand by Wheeler (1929) as *Cardiocondyla wroughtonii* var. *obscurior* and was raised to species level by Seifert (2003). Donisthorpe (1930) had also described *Cardiocondyla bicolor* from Israel but this was later synonymised with *C. obscurior* (Seifert 2003). It was first recorded for Macaronesia from Puerto de la Cruz, Tenerife in the Canary Islands in 1999 (Seifert 2003), where it was also recorded by Staab (2009), and very recently from Cape Verde (Wetterer and Espadaler 2021). However, Wetterer and Espadaler (2021) provide information on a species of *Cardiocondyla* reported by Collingwood and Van Harten (1993) from Cape Verde, which differ from *Cardiocondyla emeryi*, and have 'tentatively assumed' that these correspond to *C. obscurior*. Given this information, it is possible that *C. obscurior* has been present in Macaronesia for longer than initially thought.

In Europe, this species has been recorded from Germany (Seifert 2003), the Netherlands (Boer et al. 2018) and France (Blatrix et al. 2018), where it is an

Figure 1. *Cardiocondyla obscurior* from Funchal, Madeira, profile.

indoor exotic in greenhouses, as well as Spain where it is common in some urban environments, nesting outdoors (Valencia: Sánchez-García and Espadaler 2015; Alicante: Trigos-Peral and Reyes-López 2016; Barcelona: Espadaler and Ortiz de Zugasti 2019).

Material was compared to specimens from Gibraltar where it nests outdoors in irrigated, urban environments. This species has been found nesting in the calyx of pomegranates imported to the UK and Gibraltar from Spain (RG pers. obs). In all cases, whole nests have been found with queens, brood and males, demonstrating the ease with which a species can be transported to other countries.

Lepisiota capensis (Mayr, 1862) (Fig. 2)

Site 6. Madeira Botanic Gardens (23 Jun 2021), 4 workers on paths.

Lepisiota capensis is an African species that is extremely common in South Africa (RG pers. obs.). It has been recorded from the Canary Islands (Espadaler and Fernández 2014; Schifani et al. 2018). Collingwood and Van Harten (1993) also report *L. capensis* from Cape Verde, but according to Wetterer and Espadaler (2021) this is likely to be a misidentification of *Lepisiota canescens*. A subsequent record from Cape Verde by Báez et al. (2005) may perhaps also be a misidentification.

Table 2. Ants collected at each site in Madeira. – = 2014, + = 2021, ± = 2014 and 2021.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Cardiocondyla emeryi Forel, 1881						–		±																
Cardiocondyla mauritanica Forel, 1890					–			±	+		+				+							+		
Cardiocondyla obscurior Wheeler, 1929						+				+	–							+						
Hypoponera eduardi (Forel, 1894) *cf.*		–																						
Hypoponera sp. 1 *sensu* Wetterer et al. (2007)																+								
Lasius grandis Forel, 1909	±				–	+	+	±	+	+	+	+	+		+	+	+	+		+	+	+		
Lepisiota capensis (Mayr, 1862)						+																		
Monomorium carbonarium (Smith, 1858)						+									+									
Monomorium subopacum (Smith, 1858)											+				+									–
Myrmecina graminicola (Latreille, 1802)		–																						
Nylanderia jaegerskioeldi (Mayr, 1904)					–	+		±	±	+	±		+						+					
Paratrechina longicornis (Latreille, 1802)								±		+		+			+									
Pheidole megacephala (Fabricius, 1793)						–										+								
Pheidole navigans Forel, 1901					–	+		±		+	+	+												
Plagiolepis schmitzii Forel, 1895	+					±		–						+	+	+								
Tapinoma madeirense Forel, 1895	+	–	–	+																	+			
Technomyrmex pallipes (Smith, 1876)					–	–		–	–		–						+	+	+					
Temnothorax unifasciatus (Latreille, 1798)																							+	
Tetramorium caldarium (Roger, 1857)					–			±	±	+	+	+	+		+			+	+			+		
Tetramorium bicarinatum (Nylander, 1846)										+			+											

Its arrival in the Canaries is considered likely to be recent (Espadaler and Fernández 2014) so it is probable that this is also a recent arrival to Madeira. *Lepisiota frauenfeldi* cfr. *kantarensis* Forel, 1911 was also reported for the first time from Fuerteventura and Tenerife recently (Schifani et al. 2018) and this too may arrive in Madeira in due course.

Specimens were compared to the authors' material from South Africa. The petiolar spines in the Madeira specimens are longer than specimens from the Cape in South Africa but match the specimen illustrated in Espadaler and Fernández (2014) from La Gomera. The *capensis*-group of species is in desperate need of a revision and probably consists of several species (Hita Garcia et al. 2013).

Pheidole navigans Forel, 1901 (Fig. 3A–D)

Funchal, 6 sites: 5. Pestana Carlton Hotel (5 Sep 2014), 12 minors in planter; 6 Madeira Botanic Garden (23 Jun 2021), 15 minors, 5 majors, 1 alate queen, under stone; 8. Parque Santa Catarina (7 Sep 2014), 1 minor in lawn; 8. Parque Santa Catarina (22 Jun 2021), 157 minors, 15 majors in a planter, baited; 9. Funchal Promenade (26 Jun 2021), 170 minors, 24 majors, in lawn, baited; 11. Jardim do Almirante Reis (23 Jun 2021), 7 minors in lawn; 12. Jardim Municipal do Funchal (23 Jun 2021), 19 minors, 2 majors, in lawn.

This species of *Pheidole* was first collected in Funchal in 2014. It was identified as a member of the *flavens*-complex, but couldn't be identified to species level due to the lack of majors. Two *Pheidole* species from the *flavens*-complex were recently recorded from Tenerife in the Canary Islands: *P. navigans* and *Pheidole bilimeki* Mayr, 1870 (Hernández-Teixidor et al. 2020). We thus suspected that the Madeira specimens belonged to one of these species.

Figure 2. *Lepisiota capensis* from Madeira Botanic Gardens, profile.

Figure 3. *Pheidole navigans* from Funchal, Madeira **A** major worker, profile **B** major worker, head **C** minor worker, profile **D** alate queen, profile.

Figure 3. Continued.

We used keys in Wilson (2003) and Sarnat et al. (2015) to identify the specimens as belonging to the *Pheidole flavens*-complex. Specimens were then identified to species-level using Sarnat et al. (2015), who restored *P. navigans* from synonymy with *Pheidole flavens* Roger, 1863 and elevated it to species rank. Our specimens match the descriptions of *P. navigans* provided. Major workers can be separated from those of *P. flavens* by the

combination of predominantly longitudinal rugae on the posterolateral lobes, the more distinct and narrower antennal scrobe bordered mesially by strong, unbroken frontal carina, and the more continuously glossy scrobe depression (Sarnat et al. 2015) (Fig. 3B).

This species is very common around Funchal, especially in lawns and the soil of planters. A nest was found under a small stone. Where it was present, it was the fastest ant to respond to the protein baits, followed by *Lasius grandis*. This species is thought to be South American in origin and has been introduced into the Palaearctic and Nearctic regions (Sarnat et al. 2015). It was originally described from quarantined specimens entering Germany from Mexico.

Table 3. List of ants recorded from Madeira up to the present study.

Species	Last recorded	First collected/reported
Camponotus sylvaticus (Olivier, 1792) [a]	1857 (Mayr 1865)	1857 (Mayr 1865)
Cardiocondyla emeryi Forel, 1881	2021*	1894 E. Schmitz (Forel 1904)
Cardiocondyla mauritanica Forel, 1890	2021*	2002 (Wetterer et al. 2007)
Cardiocondyla obscurior Wheeler, 1929	2021*	2021*
Hypoponera eduardi (Forel, 1894) *cf.*	2021*	1847–58 Wollaston (Saunders 1903)
Hypoponera punctatissima (Roger, 1859)	2002 (Wetterer et al. 2007)	1847–58 Wollaston (Saunders 1903)
Hypoponera sp. 1 *sensu* Wetterer et al. (2007)	2021*	2002 (Wetterer et al. 2007)
Lasius grandis Forel, 1909	2021*	1847–58 Wollaston (Saunders 1903)
Lepisiota capensis (Mayr, 1862)	2021*	2021*
Linepithema humile (Mayr, 1868)	2002 (Wetterer et al. 2007)	Wollaston 1847–58 (Forel 1895)
Messor structor (Latreille, 1798)	Schmitz (1896)	Schmitz (1896)
Monomorium carbonarium (Smith, 1858)	2021*	1847–58 Wollaston (Smith 1858)
Monomorium pharaonis (Linnaeus, 1758)	1995 (Wetterer et al. 2007)	1995 (Wetterer et al. 2007)
Monomorium subopacum (Smith, 1858)	2014*	1847–58 Wollaston (Smith 1858)
Myrmecina graminicola (Latreille, 1802)	2014*	Báez 1989 (Espadaler and Báez 1993)
Nylanderia jaegerskioeldi (Mayr, 1904)	2021*	2002 (Wetterer et al. 2007)
Paratrechina longicornis (Latreille, 1802)	2021*	1847–58 Wollaston (Smith 1858)
Pheidole megacephala (Fabricius, 1793)	2021*	1847–58 Wollaston (Saunders 1903)
Pheidole pallidula (Nylander, 1849) [b]	1999	1999 M. Arechavaleta
Pheidole navigans Forel, 1901	2021*	2021*
Plagiolepis schmitzii Forel, 1895	2021*	1847–58 Wollaston (Saunders 1903)
Solenopsis (Diplorhoptrum) sp. 1 *sensu* Wetterer et al. (2007)	2002 (Wetterer et al. 2007)	2002 (Wetterer et al. 2007)
Solenopsis (Diplorhoptrum) sp. 2 *sensu* Wetterer et al. (2007)	2002 (Wetterer et al. 2007)	2002 (Wetterer et al. 2007)
Strumigenys membranifera Emery, 1869	2002 (Wetterer et al. 2007)	2002 (Wetterer et al. 2007)
Strumigenys silvestrii Emery, 1906	2002 (Wetterer et al. 2007)	2002 (Wetterer et al. 2007)
Tapinoma madeirense Forel, 1895	2021*	1847–58 Wollaston, (Saunders 1903)
Technomyrmex pallipes (Smith, 1876)	2021*	2002 (Wetterer et al. 2007)
Temnothorax unifasciatus (Latreille, 1798)	2021*	1847–58 Wollaston, (Saunders 1903)
Temnothorax wollastoni (Donisthorpe, 1940)	1847–58 Wollaston (Donisthorpe 1940)	1847–58 Wollaston (Donisthorpe 1940)
Tetramorium bicarinatum (Nylander, 1846)	2021*	Schmitz 1897, but also collected by Wollaston 1847–58, (Bolton 1977)
Tetramorium caldarium (Roger, 1857)	2021*	1847–58 Wollaston, (Saunders 1903)

* = this study. [a] = unconfirmed record, [b] = recorded from the Selvagens only.

Discussion

We recorded twenty species from Madeira, with three new records for the island – *Cardiocondyla obscurior*, *Lepisiota capensis* and *Pheidole navigans* – elevating the number of species recorded for Madeira to 31. All three species are exotics. Furthermore, the three have been recorded from the nearby Canary Islands (Seifert 2003; Staab 2009; Espadaler and Fernández 2014; Hernández-Teixidor et al. 2020) and therefore, their presence is not unexpected. *Pheidole navigans* is also reported to be spreading across the Southeastern United States (Sarnat et al. 2015) and the records from Macaronesia represent part of a more general expansion of the species.

We are uncertain whether these new exotic species will have an impact on other ant species, but the two best-known invasive ants certainly seem to be declining. We were unable to locate *Pheidole megacephala* in central Funchal. We visited some of the sites in the city reported for this species by Wetterer et al. (2007), including along the waterfront in the centre where they found it to be very common, but we did not find it. Furthermore, Wetterer et al. (2007) found *Linepithema humile* to be fairly uncommon in Madeira, except on the dry eastern tip of the island. Remarkably, we failed to record this species altogether.

We hypothesise that *P. navigans* could be displacing *P. megacephala* in the Funchal area, where the former now seems to be one of the most dominant ants and the latter has become difficult to find or disappeared altogether. Certainly, *P. navigans* responds extremely quickly to bait, recruiting many minor and major workers with remarkable speed. We only located *P. navigans* in the Funchal area and it would be of benefit to chart its expansion.

The most widespread and frequently encountered ant throughout Madeira continues to be *Lasius grandis* (Wetterer et al. 2007), a native species that dominates in the native laurisilva and other natural habitats but is also common in anthropogenic habitat. We share the view of Wetterer et al. (2006) that *P. megacephala* and *L. humile* are unlikely to have impacted on native ants significantly even at their peak and we are thus surprised that *Temnothorax wallastoni* remains unlocated, despite different surveys during the 21st Century and targeted searches for *Temnothorax*. This species has only been found once and the description is based on two workers from 'Madeira'. It seems unlikely that such a species would become extinct. Although it is recognized that Wollaston collected extensively on the island, the possibility that the specimen may have been collected elsewhere and labelled 'Madeira' in error cannot be discounted. We recommend that any future surveys for this ant on Madeira include extensive pitfall trapping in native habitats.

Regarding the old records of *Camponotus sylvaticus* and *Messor structor* (Table 3), we agree with Wetterer et al. (2007) that these species were sporadic introductions that have long since become extinct in Madeira. Wetterer et al (2006) argue that the record of *C. sylvaticus* was probably a misidentification of another exotic *Camponotus* species, imported to Madeira in infested timber, whereas the European native *C. sylvaticus* is a soil-dwelling species. It is interesting to note that *Tetramorium bicarinatum* was

last recorded by Schmitz (1897) (as *Tetramorium guineense*). Having failed to record it, Wetterer et al. (2007) suggested that this tramp species may no longer be present in Madeira. It is thus possible that the species became extinct and has recently been re-introduced. However, Schmitz's specimens were collected from Machico, where we also found it, so it is also possible that a population has remained there since its initial discovery.

New exotic species continue to arrive in Madeira and some of these could become invasive. We recommend regular surveying to intercept new arrivals and help elucidate the dynamics of interactions between invasive ants.

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